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DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

WEAPONS SYSTEMS RESEARCH LABORATORY

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SOUTH AUSTRALIA

REPORT

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ASBESTOS AS A POTENTIAL HEALTH HAZARD IN ROCKET MOTOR TECHNOLOGY

A. WILKIE

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ASBESTOS AS A POTENTIAL HEALTH HAZARD IN ROCKET MOTOR TECHNOLOGY

A. Wilkie

S U M M A R Y

The presence of airborne asbestos fibres has been monitored in areas used for static firing and post firing inspections of rocket motors and the manufacture of rocket motor components containing asbestos.

In most locations, the concentration of asbestos fibres was found to be significantly below the present acceptable level in relation to asbestosis but in two areas special procedures are necessary.

Fibre and dust removal equipment has been installed and additional safety procedures have been introduced.

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1. INTRODUCTION

The Propulsion Systems (PS) Group of the Weapons Systems Research Laboratory (WSRL) is engaged in the static firing of rocket motors and the manufacture of rocket motor components. Some of the motor components contain chrysotile asbestos in the form of Durestos(ref.1) and asbestos string compounded with carbon string and phenolic resin. Several thousand motors have been fired at four static firing sites during the past 20 years and it is known that components which contain asbestos are eroded and ablated during firing. Consequently, asbestos fibres could be present in the air immediately after a firing and could have accumulated in the buildings and area around the firing sites. The static firing sites are either open or partially enclosed and no special precautions had been applied to entry of personnel after firings, because of the suspected presence of asbestos. However, restrictions are applied at the discretion of the static firing officer for safety reasons or if noxious fumes are present.

Prompted by his own ill-health, an officer of Propulsion Division undertook air sampling tests during October 1980 and submitted the results to Superintendent Propulsion Division (SPD). Following discussion of the results by the Propulsion Division Safety Advisory Committee at its meeting on 13 November 1980, it was decided through the DRCS Occupational Safety and Health Committee to seek advice from the South Australian Health Commission (SAHC) in the matter(ref.2) with the author as the contact officer.

A subsequent inspection of the Laboratories Area static firing sites by Dr Czeslaw Grygorcewicz, Dr Leon Le Leu and Mr Greg Ellis of the SAHC, led to an agreement with SPD that a series of standard air monitoring tests be conducted by Mr Ellis of the Occupational Health and Air Quality Section of SAHC.

These tests were conducted on 16 and 17 November 1980 and 19 and 26 March 1981.

The results of the tests were discussed at meetings between scientific officers of the SAHC and senior staff of WSRL. Later, the results were presented to all technical and industrial personnel of the PS Group. Staff of the DRCS Safety Section and the Commonwealth Medical Officer attended both meetings.

2. TESTS AND RESULTS

Personal air sampling tests were made using the method described in the National Health and Medical Research Council publication "Membrane Filter Method for Estimating Airborne Asbestos Dust"(ref.8). The test method is to draw air from the region of the operator's head through a filter paper pad for a known period at a fixed pumping rate. All fibres on the pad which meet the specified size criteria are counted with aid of a microscope and the results expressed as fibres per millilitre (f/mL) of aspirated air. Tests were conducted for periods ranging between 15 and 120 min and the results notified to WSRL(ref.3,4).

2.1 Tests during static firings

Tests were conducted during two static firings of double base propellant charges in a vented vessel as part of thrust augmentation studies. A moulded Durestos insulating diaphragm from a Murawa sustainer motor(ref.5) and a 300 mm length of a Murawa transfer tube(ref.6) formed part of the equipment.

The latter is a steel tube fitted with a liner made from wound carbon and asbestos strings impregnated with a phenolic resin.

Other tests were conducted during a static firing of a Sidewinder AIM 9B motor which does not contain asbestos.

Three operators were employed on the work and the tests were conducted while they performed normal duties associated with static firing. The results are given in Table 1.

2.2 Test during cleaning of Durestos moulded diaphragms

One test was conducted during the clean-up of the Durestos surfaces of several used diaphragms. The method employed was to remove the char with a wire brush, blow off the dust with air and clear the waste by sweeping and collecting in a dust pan. Duration of the test was 15 min which is the normal time taken for cleaning a diaphragm. The results are included in Table 1.

2.3 Tests during manufacture of Durestos components

Further tests of 30 min duration were conducted during the manufacture of several Durestos rocket motor components from resinated asbestos flock(ref.1). During the operations, flock was weighed, packed manually into the mould and the filled mould fitted into a press. After the pressing operations the moulds were cleaned and the bay floor swept. One operator performed the work while another stood by as if in training. The results are included in Table 1.

2.4 Tests to establish background fibre concentration

Several tests were conducted in areas where staff members performed normal duties in the Propulsion Technology Section of PS Group and in the Propulsion Division Engineering Workshop. The duties were not associated with handling of asbestos-containing materials except when one operator (No.5) cleaned some tools and a press which had been used previously to manufacture Durestos components. No static firings were conducted during the test period.

Other tests were conducted by locating air samplers at a non-operational static firing site and under a verandah of an administrative building adjacent to a car-park and a road. The results are included in Table 2.

3. THE POTENTIAL HEALTH HAZARD

The principal asbestos-related diseases are asbestosis, mesothelioma and carcinoma of the lung (lung cancer). It has been generally accepted that health risks associated with these diseases are confined to occupational exposure and can be controlled by adequate industrial hygiene precautions. Further, it has been established that control of the risk of asbestosis in workers also substantially controls the risk of an excess of lung cancer among those workers, compared with the incidence of lung cancer in the community at large. There is strong evidence that cigarette smoking has a significant multiplicative effect on the incidence of both asbestosis and lung cancer. A comprehensive list of literature on the subject is given in Appendix 1, Nos. 6, 9, 11, 12, 18, 20, 26, 27, 29, 30, 31.

3.1 Limits for fibre concentration in relation to asbestosis

Asbestosis is generally defined as the form of diffuse interstitial pulmonary fibrosis, with or without fibrosis of the pleura, attributable to exposure to asbestos dust. It is dose related if the dose is considered as the product of the level of dust concentration and the length of exposure. It has an incubation period of between 7 and 20 years and the incidence is greatly increased by cigarette smoking.

The National Health and Medical Research Council of the Australian Department of Health has published the criteria to be used to determine the limits for occupational exposure to hazardous materials in the workplace(ref.7) and the method for determining air-borne fibre concentrations(ref.8).

The specified upper limit for concentration of asbestiform materials other than crocidolite (blue asbestos) is 2 f/mL.* This represents the long term weighted average concentration of fibres in the air inhaled by the worker. This limit is intended to control the incidence of asbestosis and perhaps an excess of lung cancer over the normal level for the community.

In the United Kingdom, limits of 12 f/mL measured over any 10 min period as well as 2.0 f/mL limit over a 4 hour period have been set(ref.9), while in the United States of America, a maximum of 10 f/mL at any time and a time-weighted average of 2 f/mL were proposed in 1972 by the Occupational Safety and Health Authority (OSHA) to operate from 1 July 1976,(ref.10-12).

It has been recognised that an absolutely "safe" level for asbestos fibre exposure cannot be defined and that industrial activities will always carry certain risks to health and safety. The current limits for asbestos concentration have been set with this in mind, so that a person working with asbestos over a period of 50 years should have only a 1 in 100 chance of developing asbestosis. However, the UK Trade Union Congress has proposed a level which they believe to be "safe" of 0.2 f/mL, that is, 1/10th of the present level, while the US National Institute of Occupational Safety and Health has suggested an even lower level of 0.1 f/mL(ref.13). The US recommendations to cover all asbestos risks(ref.14) are:-

(i) Time-weighted average exposure - 0.1 f/mL for particles over 5 μm (up to 10 hour exposure).

(ii) Maximum for any 15 min exposure - 0.5 f/mL.

It is not known if these recommendations have been accepted in the USA by OSHA.

3.2 Mesothelioma

Exposure to asbestos is thought to cause mesothelioma, a rare and untreatable cancer of the lining of the lung or the abdominal cavity, however mesothelioma can develop without known exposure to asbestos and without lung fibrosis. It is now generally believed that the disease is more likely to be caused by exposure to crocidolite rather than to chrysotile or amosite(ref.15). A positive relationship between exposure of workers to asbestos and the incidence of the disease has been established(ref.12).

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* It should be noted that the figures imply that the human respiratory system can cope with many millions of fibres in an average working day (2 f/mL = 2 x 10^6 f/m^3).

3.3 Carcinoma of the lung (lung cancer)

Lung cancer has been attributed to inhalation of asbestos fibres and in such cases it is almost always linked with heavy cigarette smoking(ref.15). Further, it has been stated that asbestos exposure levels which are low enough to prevent asbestosis should prevent asbestos-associated lung cancer (ref.15). However, they are probably independent phenomena and should therefore be considered separately for control measures.

3.4 The link with cigarette smoking

A link between the incidence of asbestos-related diseases and cigarette smoking has been firmly established and this raises the question of whether or not employees who smoke should be permitted to work in areas where asbestos is handled, regardless of the adoption of "safe" working procedures. Ethical considerations would be involved in making such a decision. However, it should be noted that Propulsion Division already ensures that workers with a history of asthma, allergies or bronchial ailments are not employed where contact with aromatic diisocyanates is unavoidable.

4. FIBRE CONCENTRATIONS DETECTED

Tables 1 and 2 show that the measured concentrations of all fibres noxious or otherwise were significantly lower than the presently accepted limit of 2 f/mL at all except two locations. It does not seem possible to reduce the concentrations of asbestos fibres at static firing sites by the introduction of new procedures or installation of new equipment but certain actions can and some already have been taken to reduce the risk to workers.

5. SAFETY PRECAUTIONS ADOPTED

A DRCS Circular No.79/5 "Asbestos" was issued on 16 August 1979 and a Propulsion Division Safety Instruction No.80/1 "Asbestos Hazard and Precautions in Rocket Propulsion" was issued on 17 December 1980 (Appendix II). The DRCS Circular discusses asbestos in general and prescribes safety precautions to be applied when materials containing asbestos are being handled or worked upon. The PD Safety Instruction is specifically directed towards PS Group activities including static firing. All safety precautions which have been introduced are consistent with the requirements of these documents.

In the case of cleaning the Durestos diaphragms (Table 1, test 3, operator 4), the method of cleaning has been changed. Abrasion of the charred surfaces has been discontinued. Components are now disassembled under wet conditions prior to cleaning, cleaned of loose material by wiping with a wet cloth and then allowed to dry.

Operators engaged in the manufacture of Durestos components from resinated asbestos flock are required to wear approved face masks (Protector type RQ2000 with cartridge type RQ74). Exhaust fans in the bays now operate continually during this work.

An approved industrial vacuum cleaner (BVC Model EV51A) has been purchased and is used for cleaning components, work benches and the floors of processing bays. Arrangements have been made for safe storage of waste asbestos and procedures for the collection and disposal of the wastes have been introduced.

6. AUSTRALIAN LEGISLATION, STANDARDS AND CODES

Legislation for the controlled used of asbestos is a State matter, but the National Health and Medical Research Council Australian Department of Health has issued "Model Asbestos Regulations" - October 1975. The regulations cover many aspects of handling asbestos safely and are used by State governments to produce their own specific regulations.

In South Australia, work with asbestos is covered by SA Government Regulation 39 "Industrial Safety Health and Welfare Act 1972 - Asbestos Work". The Department of Labour and Industry has issued a booklet "Working Asbestos Safely".

The Australian Department of Housing and Construction has issued a Technical Directive AE TD 103 "Control of Asbestos Hazards" September 1980.

7. MEDICAL SURVEILLANCE

Regular medical surveillance of asbestos workers appears to have been adopted in the USA(ref.11) and the UK(ref.15) and it is required by SA Regulation 39. Such examinations may include radiography but this is not favoured, unless a prognosis has to be checked, as a negative result gives no assurance for the future. SA Regulation 39 is very detailed concerning medical examinations of asbestos workers including radiography. Regulation 39 also requires that medical histories be retained for long periods.

Several members of PS Group have been exposed to asbestos laden dust in previous occupations, such as steam pipe lagging in Naval Service. They have expressed interest in a regular program of medical surveillance. Surveillance of workers who have been exposed to toxic chemicals, propellants with lead content and nitroglycerine has been conducted by PD for some 20 years.

8. CONCLUSIONS

Air monitoring tests in areas controlled by Propulsion Technology Section of Propulsion Systems Group have shown that asbestiform fibres are present in the air during normal operations associated with the static firing of rocket motors. The average concentration of all fibres measured during the static firings of two vented vessels containing a representative amount of asbestos was between 0.1 and 0.9 f/mL. The level of fibre concentration appeared to depend on the distance of the operator from the fired motor. A corresponding figure for the static firing of a motor which did not contain asbestos was 0.17 f/mL.

The measured concentrations are significantly lower than the present generally accepted limit in industrial areas of 2 f/mL. However, they are greater than the most recently suggested "safe" level of 0.1 f/mL for all asbestos-related health risks. Concentration levels can not be significantly reduced but application of personal protective equipment and reduction of personal exposure times can minimise the potential health hazard.

The test duration times given in Tables 1 and 2 are typical for the operations. However, the operations are carried out only intermittently and for the remainder of their working time operators would be exposed only to the background levels of fibre concentration. As these are significantly below the suggested "safe" limit, it can be expected that the time-weighted average fibre concentrations to which the operators are exposed will approach this "safe" limit.

Some unacceptable fibre concentrations were detected during operations associated with the manufacture of Durestos components and the cleaning of these components after static firings. New procedures have been developed for these operations.

A study of the literature on asbestos related diseases shows that the incidence of asbestosis, lung cancer and mesothelioma in relation to asbestos exposure has been proved. The connection of cigarette smoking with asbestosis and lung cancer has been clearly established.

9. RECOMMENDATIONS

The following recommendations are proposed for adoption in Propulsion Division WSRL:

(i) That the safety precautions detailed in PD Safety Instruction 80/1 "Asbestos Hazard and Precautions in Rocket Propulsion" and the additional precautions and changed procedures introduced into Propulsion Technology Section of Propulsion Systems Group be included in the written procedures for the various operations.

(ii) That consideration be given to the medical surveillance of all workers who are exposed to asbestos.

(iii) That all employees who smoke cigarettes and are exposed to asbestos be apprised of the firmly established association of cigarette smoking with asbestosis and lung cancer.

(iv) That effort be directed towards evaluation, development and application of alternatives to asbestos in rocket propulsion technology.

10. ACKNOWLEDGEMENTS

The cooperation and advice given by the officers of the South Australian Health Commission and in particular, that given by Mr G. Ellis who performed the tests, is gratefully acknowledged.

Many of the references quoted and the extensive bibliography given in Appendix I were provided by Mr E.F. Shepherd, Mechanical Engineering and Workshop Division, Advanced Engineering Laboratory.

The cooperation of the staff of PS Group who were involved in the tests is acknowledged.

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APPENDIX I

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Note: References 26 and 27 should be read in conjunction with each other.

APPENDIX II

PROPULSION DIVISION - SAFETY INSTRUCTION NO. 80/1

ASBESTOS HAZARD AND PRECAUTIONS IN ROCKET PROPULSION

1. The problem of asbestos fibres and their potential for causing asbestosis has been known for many years. In recent years there has been an increasing awareness of how widespread the problem may be and the use of asbestos is being subjected to increasingly rigorous scrutiny. In many respects asbestos is a unique material and for some applications satisfactory alternatives are not available. Where its use cannot be avoided, risks associated with its use must be circumvented with adequate precautionary measures.

2. In this Division we have, for many years, been conscious of the need for due care in the use of asbestos and asbestos-containing materials for high temperature thermal insulation. The asbestos hazard potential, particularly in rocket motor static firing sites and during post-firing operations, has been reexamined by the Propulsion Division Safety Advisory Committee.

3. More recently consultative specialist advice has been sought from the Occupational Health and Air Quality Group of the South Australian Health Commission. Officers from the Commission, experts in asbestos/asbestosis problems, have inspected Propulsion Division operations and arrangements have been made for a series of tests to be conducted. From their inspections, the interim advice of these consultants is:

(a) In firing sites the standard of housekeeping and cleanliness, and ample ventilation are such that asbestos fibre potential is very low

(b) At rocket motor firing temperatures asbestos undergoes a phase change to non-hazardous serpentine but it is possible that some asbestos may escape unchanged in the exhaust

(c) Greater potential for hazard exists in work places where asbestos-containing materials are machined or abraded. Transitory peak exposures are less hazardous than continual exposure. Positive removal of dust and machinings from work faces by suction is desirable and the wearing of approved appropriate filter masks is recommended

(d) No hazard arises from the use of unpainted asbestos/cement sheet panelling on or in buildings

4. Safety precautions and instructions will be reviewed in the light of the SA Health Commission tests and investigations. In the meantime the following instructions are to be strictly adhered to:

1. No personnel shall enter a rocket motor firing site within the first ten minutes after completion of the firing of any motor

2. During cleaning, abrading and machining of asbestos-containing materials, personnel engaged in or observing these operations shall wear Protector type RQ 2000 respirators with cartridge type RC 74

5. Staff are reminded of two further potential hazards and safety instructions, associated with rocket motor firings, which are to be borne in mind at all times.

(a) Rocket motor exhaust gases contain toxic and other hazardous constituents. Avoid breathing fumes arising during breakdown and disassembly operations on fired rocket motors.

(b) Chars and tar residues in or from fired motors may be toxic or hazardous and skin contact with them should be avoided. Gloves and other protective clothing as appropriate are to be worn.

TABLE 1. AIR SAMPLING TESTS DURING NORMAL OPERATIONS

Operator No.	Operations performed	Asbestos Dust Concentration (f/mL)	Nominal Test Duration (min)
1. Vented vessel firing			
1	Assembly of vessel and first static firing	0.68 - 0.51	120
2	Assembly of vessel and first static firing	0.63 - 0.46	120
3	Assembly of vessel and first static firing	0.20 - 0.12	120
1	Disassembly of vessel followed by reassembly	0.74 - 0.57	120
2	Disassembly of vessel followed by reassembly	0.89 - 0.73	120
1	Second static firing and disassembly	0.10 - 0.07	120
2	Second static firing and disassembly	0.16 - 0.13	120
2. Sidewinder AIM 9B static firing			
1	Static firing	0.17 - 0.00	120
2	Static firing	0.17 - 0.00	120
3. Cleaning Durestos diaphragms			
4	Cleaning surfaces with wire brush and sweeping bench	7.5 - 7.3	15
4. Manufacture of mouldings from resinated asbestos flock			
5	Weighing flock, filling mould and operating press, sweeping bench and floor	4.3	30
6	Operator-in-training standing by in bay but remote from operations	0.4	30

TABLE 2. AIR SAMPLING TESTS IN PROPULSION DIVISION TO ESTABLISH BACKGROUND FIBRE CONCENTRATIONS

Operator No.	Operations Performed	Fibre Concentration (f/mL)	Test Duration (hour)
4	Rocket motor disassembly and cleaning of components with wire brush in building 18.	0.03	3.4
6 (Technical Officer)	Supervisory duties and inspection of static firing sites. Assisting in calibration of test equipment in a static firing site and general office duties in the Section Office.	0.01	3.5
5	Rocket motor lining in buildings 19 and 29, assisting in grit blasting at building 11. Cementing a liner into a motor and cleaning of tools and the hydraulic press previously used to manufacture Durestos components	0.06	3.4
7 & 8 (Toolmakers)	Normal workshop duties in building 75.	0.03, 0.03	2.5, 3.3
-	Eastern verandah of building 75	0.01	5.5
-	Adjacent to Static Firing Site 1, building 163	0.01	5.4

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16 SUMMARY OR ABSTRACT:
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The presence of airborne asbestos fibres has been monitored in areas used for static firing and post firing inspections of rocket motors and the manufacture of rocket motor components containing asbestos.

In most locations, the concentration of asbestos fibres was found to be significantly below the present acceptable level in relation to asbestosis but in two areas special procedures are necessary.

Fibre and dust removal equipment has been installed and additional safety procedures have been introduced.

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